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# CONSTRUCTION INNOVATION: A LITERATURE REVIEW ON CURRENT RESEARCH

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**ABSTRACT:** Innovation in construction is a subject being discussed during a considerable period of time. However current research and statistical data shows that construction is lagging behind other sectors in the aspects of productivity and efficiency for which lack of innovation is blamed. This paper is an effort to illustrate present status of construction innovation research and perceptions of researchers and practitioners based on a review of current literature. Emphasis was placed on identifying the prevailing nature of construction innovation with reference to enabling and disabling factors and ways to improve the performance of construction to address the stakeholder needs.

**Keywords-** Construction Industry, Construction Innovation

## 1 INTRODUCTION

The construction industry is being increasingly challenged to successfully innovate in order to satisfy the aspirations and needs of society and clients, and to improve the competitiveness (Latham, 1994). Number of definitions is given for innovation within the literature. Dulaimi (2005) identifies innovation as the generation, development and implementation of ideas that are new to an organisation and that has practical or commercial benefits. It is generally accepted that innovation is the implementation of significantly new processes, products or management approaches in order to increase efficiency of an organisation (Seaden, 2003). The work of Sexton and Barrett (2003) emphasis that for an innovation to be successful, *new ideas* should be followed by *effective implementation* and must *improve overall organisational performance*. Further it was agreed among researchers (Dulaimi, 2005, Seaden, 2003, Sexton and Barrett, 2003) that ideas should not necessarily be new to the world, but to the organisational context under concern to generate innovation.

The main aim of this literature review is to identify the prevailing knowledge regarding construction innovation in order to identify areas which require further investigation. The literature was organised under four main sections. In the first section nature of construction innovation is discussed, highlighting the specific characteristics. This is followed by facilities to enhance construction innovation and barriers to construction innovation in section two and three respectively. The emphasis of section four is on implementation and management of innovation towards the envisaged goals of the construction industry. Finally the paper is concluded with a conclusion from literature reviewed.

## 2 NATURE OF CONSTRUCTION INNOVATION

What is the status of construction innovation? Is the industry innovative compared to other main industrial sectors? There are literature to state that construction lags behind the innovativeness of the manufacturing and services sectors. Productivity growth in construction is far below the national average (Nam and Tatum, 1997). In contrast there is literature stating that engineering and construction projects are inherently innovative (Pries and Janszen, 1995; Tatum, 1986; Tatum 1984). The project base nature of construction industry

makes every project unique (Veshoskey, 1998), thus there is significant opportunity and tendency for new approaches. Building practitioners and their clients have often interpreted these new approaches as innovative behaviour (Seaden and Manseau, 2001). On the other hand uniqueness was criticised as a hindrance for construction innovation. Due to the unique conditions contractor has little to gain from being innovative, other than optimisation of their own process. The economies of scale rarely exist and knowledge gains are rarely being transferred (Pries and Janszen, 1995). There are observations to suggest the effect of uniqueness on innovation depends on the nature of the projects. In the study of use of virtual reality in construction industry, Whyte (2003) identifies that small projects with design reuse and large unique projects motivate use of virtual reality innovatively. When the company is small and work is repetitive it is possible to harvest higher return with comparatively smaller investment on technology. On the other hand large complex projects make room for innovation to overcome the associated practical problems.

Regardless whether the construction industry is innovative or not; there are concerns over the lack of systematic diffusion of innovation through the industry. The Business Roundtable (1982, cited in Nan and Tatum, 1997) attributes lack of innovation not to the lack of capability, but to the absence of a coordinated effort to link market needs and inventive capacity in spite of adequate demand pull as well as supply of promising technologies, such as computers, robotics and advance materials that are standing ready till being utilised through coordinated system. Further, innovations developed to solve problems at project levels are not effectively documented or communicated to others for future reference (Veshosky, 1998) and are rarely commercialised by manufactures (Slaughter, 1991).

Empirical study conducted by Reichstein et al, (2005) using the data form 'UK innovation survey' found out that number of firms engaged in product and/or process innovation in construction sector is lesser than other sectors. Further it was found out that construction firms are less open to the external environment and they tend to have poorly developed research and development (R&D), with low capacity to absorb ideas from external. However, some researchers are skeptical about so called conclusive evidence of the poor performance of the construction industry *compared with* other industrial sectors. Winch (2003) attributes that this observation to the deficiency of Standard Industrial Classification (SIC) on which most researchers categories statistics regarding construction and other sectors. Construction sector in SIC excludes Architectural and Engineering Consultancy firms where large amount of innovative designs are carried out. Further large proportion of value added in construction sector is repair and maintenance work where room is limited for innovation and productivity is low due to the nature of work. Nevertheless, this is not the case in most of the other industries or not significant as such. Thus it can be argued that construction sector under SIC is not comparable with other industries. However, Winch (2003) admits that there is insufficient evidence to state that the construction industry is any worse or better compared to other industries.

The question 'is the industry truly innovative, i.e. good at adopting new processes and products?' still remain without a clear answer. Unfortunately, official statistics are limited in measuring innovation and existing measures are related to the R&D statistics. R&D expenditures, number of R&D personnel, number of patents, number of publications and their citations, etc are considered as indicators of measures of R&D performance, thus for the innovation (Seaden and Manseau, 2001). Is R&D an indicator of innovation? OECD (1996, 1997) has reported that innovation can emerge from various sources of activities, and not only from R&D, although it constitutes an important part of innovation activities. The study of Slaughter (1991), also attest to this statement where majority of innovation was originated at sites by the builders (see section 3). Kline (1985, cited in Seaden and Manseau, 2001) states that research is not the direct source of innovations, and much innovation proceeds

with little or no input from current research. Nevertheless, the level of R&D activity has been positively correlated with the relative innovativeness of various industrial sectors, particularly high tech manufacturing sectors, therefore considered as a valid indicator of innovation (Seaden and Manseau, 2001)

In recent era construction companies are keen on innovation. Due to the escalating labour charges construction companies identify innovation as a means of being competitive in the international markets (Nam and Tatum, 1997). This fact is reflected by the use of “innovative”/ “innovation” words in the company brochures and other marketing documents (Nam and Tatum, 1997).

The above section discussed different opinions regarding the innovativeness of the construction industry and how the characteristics of the industry has influence the innovation. Following section will look into the facilities to enhance innovation within construction industry.

### **3 FACILITIES TO ENHANCE CONSTRUCTION INNOVATION**

One of the principal themes in the management of innovation is that, ‘innovativeness’ of the organisation and the extent to which the design of the organisation facilitates or inhibits innovation (Winch, 2000). According to Winch (2000), organisations that are relatively programmed and planned have more difficulties in innovation. This was confirmed in the comparative study on the innovativeness of French and British construction organisation involved in Channel Tunnel project. Based on case studies it was found out that the French were more ready to make process improving innovations than their British counterparts, particularly through the use of automated systems. Winch (2000) attributes this difference to the organisation structure, culture and behaviors of team members. One important difference is the allocation of roles. French had unitary hierarchy with multi skilled managers. In contrast British had multiple hierarchy composed of different, more narrowly defined skills. Further British method of working is more procedural compared to French.

Tatum (1989) found out that to foster innovation, there must be implicit vertical integration. This fact is confirmed by Dulaimi *et al.* (2002), who states that procuring more contracts based on design–build method would enable companies to increase their innovation, compared to design–bid–build, which is known to be one of the causes of fragmentation (Ling, 2003).

To increase the probability of successful innovation, implementation should be preceded by searching for alternatives, evaluating them and justifying the cost (Ling, 2003). Nevertheless, it should be noted that innovation does not originate only from R&D or from manufacturing facilities; but from users as well (Slaughter, 1991). Users innovate when the technology is easy to modify, specifically when the cost for the user to innovate are decreased (Slaughter, 1991). This fact was proven in the detailed field study of a single major innovation in the construction of residential housing; the stressed-skin panel, and innovations relating to its installation. Major finding was that users of stress-skinned panel (in this case the builders) are the main source of innovation who innovate 80% of innovations studied. This research intends to suggest that “learning-by-doing” and user innovation during implementation can be viewed as an iterative process that can push forward the development of a technology (Slaughter, 1991).

Kangari and Miyatake, (1997), identify four main factors that contribute to innovation in Japanese construction industry as: strategic alliances; effective information gathering capabilities; reputation through innovation and technology fusion. The link between innovation and business strategy in a large construction firm in Japan was found to be the

long-range technology forecasting that integrates action of today with the vision of tomorrow (Kangari and Miyatake, 1997).

Information plays a key role in innovation as in many other situations. Lack of information regarding innovation is identified as a barrier by Project Managers (Veshosky, 1998). However there were companies that provide information sources but their availability were not properly communicated to the Project Managers thus proper utilisation was not achieved. Further, lack of focus of innovation in external sources was observed, which hinders the ability to learn from others experience and develop the industry as a whole (Veshosky, 1998). Therefore, it can be said that accessibility to information is essential to promote innovation. Veshosky (1998) have come across positive actions which certain companies have taken to improve the information flow to key personnel. They are:

- Assigning responsibility for managing innovation information to a specific individual or group;
- Maintaining a file or database of innovation information;
- Conducting internal technical seminars;
- Producing internal technical reports;
- Providing library capabilities including electronic information services;
- Encouraging project managers and engineers to interact with windows to external; and
- Encouraging project managers and engineers to participate in professional activities;

Early research has identified the importance of client to promote innovation. The Business Roundtable (1981, 1982, cited in Nam and Tatum, 1997) claimed that technological progress in construction requires the clients' involvement and leadership. In most cases, the willingness of client for risk sharing, commitment to innovation and leadership in project planning and execution seemed to be critical for the success of the innovation process (Nam and Tatum, 1997). The research suggest that there might be a close relationship between the clients' technical competence and their active participation in the project or at least a better understanding of technical matters for timely approval of innovative ideas. In addition, the clients' important role as the leader of the project appeared to influence the project environment by encouraging more integration among project participants. On the other hand, lack of above mentioned capabilities by the client may negatively effect the innovation. Ivory (2005) studied three projects where the influence of client had adversely effect the innovations. In this particular three case studies desire of clients to avoid risk associated with the innovations were highlighted. In each case, it is clear that the clients actively sought to control innovation and to ensure that it did not threaten the project or the resulting buildings (Ivory, 2005). However the case studies also provided some insight to the reasons behind the suppression of innovation. The dangers to clients of innovation stem both from short-term consequences, such as late or over-budget projects and from longer-term issues, hidden amongst the 'unknowns', such as higher than expected running costs or maintenance bills. In two case studies it was noted that the benefits of innovations were targeted at the users, but the paying client did not benefit from them. On the other hand client was facing the danger of criticism if the innovation failed. Further, in some instances clients simply failed to see the benefits of the innovation. Despite the arguments the projects studied were highly client focused, but the criticism is from the aspect of the encouragement to innovation. Ivory (2005) argues that the clients' intention of using established innovations rather than taking risks in new innovations hinder the advancement of technological frontier which can cause adverse effect to the industry in long term.

Above section identified the factors that positively influence the construction innovation. Further, it was revealed, how important the commitment of client for construction innovation

and how lack of clients commitment to innovation can become a barrier. The following section further discusses barriers to construction innovation.

#### **4 BARRIERS TO CONSTRUCTION INNOVATION**

The fragmented nature of the construction process is identified as the main barrier to innovation (Pries and Janzen, 1995). Contractors and consultants are isolated from one another and contractors are often of small size and fragmented (Gann 2000). Moreover, construction projects also have a significant coordination and integration problems due to extreme specialisation of functions and/or involvement of various professions (Nam and Tatum, 1992). On the other hand the fragmentation of the professional bodies in construction has weakened their ability to act as honest brokers of innovation as they typically threaten the interests of one or other amongst them (Winch, 1998).

The particularly long life span of the construction products are also viewed as a barrier to innovation as it compels the client to stick to known methods rather than being radically innovative (Blayse and Manley, 2004). Since risk of failure is higher in construction, trial-and-error approach is not much acceptable (Nam and Tatum, 1997).

Due to technical regulations the room to be innovative is restricted (Blayse and Manley, 2004; Veshosky, 1998). Pries (1995, p: 45) exaggerates the scenario to the extent of stating that the “enterprises do not produce for the client; they produce to meet government regulations”. The research of Bowle (1960, cited in Ling, 2003) provides evidence to that restrictions imposed by regulations have been a hindrance to the construction innovation for a long time.

The construction industry is also known for conservatism; professionals cling to an accepted industry practice and norms in fulfilling client’s need; changes are taken as a threat, and slack resources are rarely permitted (Nam and Tatum, 1997). These statements were confirmed in the interviews conducted by Dulaimi (2005). In the interviews some Project Managers had expressed concerns that innovators who may go beyond established organisational policies and practices might trigger an increased risk on the project objectives. In this context, securing the support of project parties may become increasingly challenging. Many Project Managers have also referred to the very tight schedules, undue emphasis on cost-cutting measures, economic recession and lowest bidding practice that impeded their actual ability to innovate. Veshosky (1998) also received similar comments from the Project Managers. Further he observed very diverse opinions about innovation. Some Project Managers state that they don’t do innovation because it is against organisational and industrial culture. Whereas some Project Managers considered innovation as “sustainable competitive advantage”

The commitment from top management and the level of technical expertise have been evident as preconditions for successful innovation in construction (Nam and Tatum, 1997). Top executives in innovative organisations appear to assume responsibility actively for technological decision making and have sufficient technical expertise to do so. Nevertheless many managers, in particular high level managers, in construction industry appear to have a limited view concerning their roles in the innovation process. They no longer see themselves as engineers who actively make technical decisions; they claim that their roles as managers prevent them from being personally involved in engineering. The belief in the supremacy of management (including marketing, customer contact and management of R&D) over engineering appears common in design and construction (Nam and Tatum, 1997). However, the suggestion of Nam and Tatum (1997) that the construction should be managed by technically competent people is not always supported. Pries and Janszen (1995) identifies

'engineer's paradigm' or strict technical focus as a barrier to innovation. Pries and Janszen (1995)'s study revealed that only 4% of the managers have a degree in economics or management subjects, while 51% are engineers, 2% have law degrees and the rest didn't have any academic qualification at all. All of them were gradually promoted to the top management position which is perceived to be superior as Nam and Tatum (1997) implies. In the authors' opinion this pattern of promotion had resulted in placing engineers and technicians in a dilemma between practicing their technical skills where they are good at, and performing managerial tasks where they lack competence. Thus innovative ideas may not be managed prudently to gain expected results. In the following section it is further discussed how the innovation should be managed towards achieving the goals of the construction industry.

## 5 INNOVATION IMPLEMENTATION

The literature identifies two broad variables that govern the decision of innovation i.e. business environment and business strategy. Further, size of firm and its specialisation is also to be considered. The study conducted by (Seaden, 2001) on Canadian construction industry revealed that smaller firms being more risk averse, with lower intensity of use of innovative practices, whereas a greater percentage of larger firms reported adopting technological or business changes with significant impact on their business.. However Blayse and Manley (2004) contradict the lower intensity of innovation of smaller firms as the research conducted suggest approximately 75% of innovations emerged from smaller firms. Nevertheless, they further state that majority of innovations from the smaller firms are process innovations. Regardless to the intensity of innovation, smaller and particularly medium size firms indicated that such changes provided them with bigger competitive advantage when compared to large firms

One school of thought suggests that the innovation can only create competitive advantage when managed properly (Pries and Janszen, 1995). Another school of thought takes the view that innovation is unmanaged self organise processes originating due to collective motivation of individuals (McElroy, 2002). However the project based nature of construction industry and the participation of number of organisations with varying competencies make implications on both schools of thought. Fragmentation make initiation and implementation of innovation difficult and challenging (Kangari and Miyatake, 1997), therefore the management of innovation as well. The fragmentation gives rise to separate managerial roles from each participant who tries to integrate effort of the project toward innovation. Under this fragmentation, success in innovation relies on two major aspects: high intra-organisation motivation and good inter-organisational interaction (Dulaimi et al 2003) Construction typically has two separate systems integrators: one at the design stage and the other at the construction stage (Winch, 1998) which generally hinders the ability to innovate. Therefore need for the compatible management systems among stakeholders is emphasised to reinforce integration across construction value chain (Dulaimi, 2002). For an innovation to be successful, it would be necessary for firms to work together, erode boundaries between professions and for project-based firms to embrace new roles and develop new capabilities (Gann, 2000).

However, there is literature to show how these different integrators can facilitate innovation. Many researchers have stressed the importance of key individuals in the innovation process (Nam and Tatum, 1997). The Project Manager is often identified as a person who can focus the fragmented effort towards common goal. Dulaimi (2005) agrees that the innovation at site is positively related to the championing behavior of the Project

Manager. Thus, Project Managers need to exhibit commitment in the innovation process by expending their energy, taking responsibility and reasonable amount of risk. Further positive relationships are established between Project Manager's level of education, size of project and innovativeness of Project Manager's problem solving style to the level of innovation at site (Dulaimi, 2005). Studies of Ling (2003) conducted on construction industry of Singapore shows that interest level of the main consultant when the innovation is being implemented plays a major role in convincing team members of the benefits of innovation.

Identification of key factors is important to manage innovation towards expected goals. Ling (2003) states that to improve the possibility of innovation, expected goals of the innovations should be clearly laid out to the team members, further maximisation of capabilities and commitment exerted at the management and project levels and minimisation of constraints and challenges are also important. Dulaimi et al (2003) agrees with Ling (2003) stating that an innovation may be successfully implemented in the project if effort is put into carrying the innovation through, and there are high expected goals, favourable results and high commitment.

Dulaimi et al (2003) emphasis the need of proper plan to implement innovation with regard to other participants. Organisations that are in pursuit of innovation can derived there plans based on existing models of innovation such as Incremental innovation, Modular innovation, Architectural innovation, System innovation and radical innovation (Slaughter, 1998). Eaton (2001) supports the view that innovation should be selected to suit the context of innovation. He proposes a model which consists of an ordered set of four epochs (factor condition epoch, investment condition epoch, innovation condition epoch, and wealth condition epoch) in which different types of innovation strategies are required. Eaton (2001) further identifies pattern that organisations moves through these epochs, and propose five typologies. A construction organisation in pursuit of innovation can decide on the best suited typology to choose based on epoch it is in.

## 6 CONCLUSION

Is construction innovative or not? There is literature, as summarised above, to suggest yes as well as no. In the support of innovativeness some argues that the unique nature of each project provides significant opportunity to innovate. Nevertheless, uniqueness is criticised as hindrance as it discourages expenditure on innovation or R&D. Similarly there are diverse views about use of innovation. Some professionals state that they don't do innovation because it is against organisational and industrial culture, whereas some considered innovation as "sustainable competitive advantage". In the authors opinion all these observations are governed by its own context, without reference to the context it is impossible to state which is right or wrong.

Regardless whether the construction industry is innovative or not; there are concerns over the lack of systematic diffusion of innovation through the industry. Previous research attributes lack of innovation not to the lack of capability, but to the absence of a coordinated effort to link market needs and innovative capacity. Productivity growth in construction is far below the national average. Number of firms engaged in product and/or process innovation in construction sector is lesser than other sectors. Further it was found out that construction firms are less open to the external environment and they tend to have poorly developed R&D, with low capacity to absorb ideas from external due to lack of focus of innovation in external sources. However, R&D cannot be considered as a direct measure of innovation despite positive correlation. There are number of occasions where innovation stemmed away from



R&D facilities. Unfortunately, due to limited official statistics regarding innovation, measures related to R&D is used to access innovativeness.

Structure of industry and constituent organisations affects the level of innovation. It was generally accepted principle that organisations that are relatively programmed and planned have more difficulties in innovating. The fragmented nature of industry, very tight schedules, undue emphasis on cost-cutting measures, economic recession and lowest bidding practice are criticised as a barrier to innovation,

There were concerns regarding the diffusion of benefits of innovation as well. Some research implies that the reluctance of clients to facilitate innovation may be due to the inappropriate diffusion of benefits. If the paying client is to take all the risk of the innovation while the benefit is targeted at the users (in a case of public building or apartment for rental etc) the client may suppress innovation. There is a possibility for this phenomenon to affect other team members as well.

Most researchers suggest the need to eliminate fragmentation to the point that is practical. There is a need for the compatible management systems among stakeholders and to improve the possibility of innovation, expected goals of the innovations should be clearly laid out to them

Finally authors conclude this paper by identifying diffusion of innovation, diffusion of knowledge regarding innovation, diffusion of innovation benefits within construction industry, organisational structures and cultures that promote innovation, management and coordination problems in innovation and measures to assess innovation as areas that requires further study to identify knowledge gaps to be researched in future.

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